Available online at sjuoz.uoz.edu.krd

Science Journal of University of Zakho

Vol. 13, No.4 pp547–557October-December,2025

p-ISSN: 2663-628X
e-ISSN: 2663-6298

IMPACT OF VITAMIN D STATUS, IRON PROFILES, AND TRACE ELEMENTS IMBALANCES ON CARDIOMETABOLIC RISK FACTORS IN WOMEN WITH SUBCLINICAL HYPOTHYROIDISM

Chiman H. Sulaiman[1, *], Lina Y. Mohammed[2], Mohammed A. Hami[1]

[1]Chemistry Department, College of Science, University of Zakho, Kurdistan Region, Iraq.
[2]Department of Biomedical Science, College of Medicine, University of Zakho, Kurdistan Region, Iraq.

*Corresponding author email: chiman.sulaiman@staff.uoz.edu.krd

Received: 24 Apr 2025 Accepted:22Jun 2025 Published:7 Oct 2025 https://doi.org/10.25271/sjuoz.2025.13.4.1560

ABSTRACT:

The main aim of this study was to elucidate the impact of vitamin D, iron profile, and trace elements imbalances on cardiometabolic risk factors in newly diagnosed women with subclinical hypothyroid. Fifty newly diagnosed subclinical hypothyroid (SCHT) females, aged 18-50 years, and 40 healthy females matched in age with patients were enrolled in the present study. Thyroid-stimulating hormone (TSH), Free thyroxin (FT4), Free triiodothyronine (FT3), vitamin D, and serum ferritin were measured using an electrochemiluminescence assay. Lipid profile, serum iron (Fe), and unsaturated iron binding capacity (UIBC) were analyzed by a photometric measuring unit. Serum zinc (Zn), magnesium (Mg), and copper (Cu) were quantified using a colorimetric method. The current study indicated a significant increase in cardiometabolic risk factors such as fasting blood sugar (FBS), lipid profile, Triglyceride-glucose index (TyGi), and Atherogenic index of plasma (AIP) in SCHT, in contrast to the healthy group. Furthermore, a strong association was noted between elevated TSH and lipid profile, fasting blood sugar, AIP, and TyGi. Additionally, a substantial association was indicated between reduced vitamin D, ferritin, magnesium levels, and elevated copper levels with cardiometabolic risk factors. The current study concluded that low vitamin D, ferritin, magnesium levels, and elevated copper levels are linked with cardiometabolic risk factors in females diagnosed with subclinical hypothyroidism. Reduced vitamin D, magnesium levels, disrupted iron metabolism, and elevated serum copper were linked to heightened atherogenic risk and metabolic abnormalities.

KEYWORD: cardiometabolic risk factors, subclinical hypothyroidism, vitamin D, iron profile, trace elements

1. INTRODUCTION

Subclinical hypothyroidism (SCHT) is a biochemical disorder characterized by elevated concentrations of thyroid-stimulating hormone (TSH) in the blood, with normal concentrations of triiodothyronine (T3) and thyroxine (T4) in the peripheral thyroid. The prevalence rate of SCHT has been steadily rising over the past few years, especially among the elderly, and ranges from 5 to 20% in the general population. Subclinical hypothyroidism (SCHT) can present with or without symptoms, depending on the individual. Some of the most common signs of SCHT include mild depression, fatigue, weak muscles, weight gain, and cold sensitivity (Hamad & Raziq, 2020; Wang *et al*., 2024). An increased risk of cardiovascular disease (CVD), mortality, and coronary artery disease due to coronary diseases is associated with SCHT. Moreover, patients with SCHT in middle age may exhibit cognitive impairment, nonspecific signs such as emotional disturbances and fatigue. Additional cardiovascular risk factors, such as alterations in pulse and atherosclerosis, have been correlated with SCHT (Biondi *et al.*, 2019). CVDs like heart failure, atrial fibrillation, pericardial effusion, mitral valve dysfunction, and atrial tachyarrhythmia are linked with thyroid dysfunction (Lamichhane *et al.*, 2023).

Around 30-60% of the population, including adults and children, suffers from vitamin D deficiency or insufficiency; this has become a significant public health concern worldwide (Gallagher & Rosen, 2023). Vitamin D and thyroid hormones operate through analogous nuclear receptors and are expected to influence each other's effects. Hypothyroidism and hypovitaminosis D have been linked by multiple researchers (Ahi *et al.*, 2020; Appunni *et al.*, 2021). Type 1 diabetes, cardiovascular disease, certain malignancies such as breast cancer, autoimmune disorders, and melancholy have all been linked with a deficiency of vitamin D, an essential nutrient for the body (Hanna *et al.,* 2021; Pál *et al*., 2023; Giustina *et al.*, 2024).

Metabolism and proper functioning of the thyroid gland depend on trace elements (TE), which are vital structural components of thyroid hormones (Bílek *et al.*, 2020). The thyroid endocrine system can be adversely affected by deficiencies in selenium (Se), copper (Cu), iodine (I), iron (Fe), manganese (Mn), and zinc (Zn). These TE contribute to combating oxidative stress as constituents of enzymes (Hami *et al*., 2016; Wróblewski *et al.,* 2023). Recent studies have indicated a clear correlation between TE, including Zn, Se, Mn, Cu, and Mg, and cardiovascular risk factors, as these TE can function as both pro-

* Corresponding author

oxidants and antioxidants, contingent upon various circumstances (Barragán *et al.*, 2022; Zarmina Khan *et al*., 2025). Iron is a vital nutrient necessary for numerous physiological functions. Iron deficiency (ID) is a prevalent nutritional problem globally, impacting around two billion individuals, predominantly women of reproductive age and pregnant women (Kumar *et al.*, 2022). The deficiency of iron storage significantly affects the thyroid gland's functionality and hormone production, which is essential for biological processes in the body. Hypothyroidism can lead to iron deficiency anemia by undermining the body's ability to absorb iron (Abdulmawjood & Altamer, 2024). ID frequently occurs in individuals with cardiovascular disease. As many as 60% of individuals with coronary artery disease, and an even greater percentage of those with pulmonary hypertension or heart failure, have ID (Savarese *et al.*, 2023). The primary aim of this study was to elucidate the impact of vitamin D, iron profile, and trace element imbalance on cardiometabolic risk factors in women with subclinical hypothyroidism. Considering the well-documented correlation between vitamin D, iron deficiencies, trace elements imbalance, and various cardiometabolic risk factors.

2. MATERIALS AND METHOD

Study Area, Period, and Design:

This hospital-based quantitative cross-sectional study was conducted from November 2024 to January 2025 at Zakho General Hospital, Zakho City, Kurdistan Region, Iraq.

Study Population and Selection:

A total of 90 female subjects, aged between 18 and 50 years, were enrolled in the study. The cohort included 50 newly diagnosed subclinical hypothyroid female subjects with normal FT3, FT4 levels, and TSH > 4.2 pmol/L as cases, and 40 subjects who were matched with the study group in terms of gender and women of reproductive age as the control group, were admitted to the hospital for a health assessment.

Exclusion criteria for both healthy volunteers and SCHT patients included: medications capable of inducing thyroid dysfunction, diabetes mellitus, pituitary/hypothalamic disorders, liver disorders, renal disorders, dyslipidemia, cardiovascular disease, hypertension, acute or chronic systemic disease, polycystic ovary syndrome, thyroid supplements, medications that might alter iron metabolism and 25-OH vitamin D or thyroid functions, vitamin D, calcium, iron, zinc, magnesium, vitamin B12, or vitamin C supplementation, pregnant, menopause, lactating mothers.

Blood Collection and Biochemical Assessment:

Following an overnight fast of 10 to 12 hours, 5 milliliters of venous blood samples were obtained in the morning between 8:00 and 10:00 AM, placed in a gel tube, and left to stand at room temperature for about thirty minutes. The sample was centrifuged at 5000 rpm for approximately 10 minutes, after which the sera were partitioned into three aliquots for specialized analyses and stored at -80°C in a freezer for biochemical research. Fasting blood sugar (FBS), Triglyceride (TG), Total Cholesterol (TC), High-density lipoprotein cholesterol (HDL-C), TSH, free thyroxine (FT4), free triiodothyronine (FT3), Vit D, iron, unsaturated iron binding capacity (UIBC), and ferritin were analyzed by the immunoassay method using a Cobas 6000 automated analyzer (Roche, HITACHI). Total iron binding capacity (TIBC) is expressed as TIBC S. Iron + UIBC. Very low-density lipoprotein (VLDL), Total Cholesterol (TC), and atherogenic index of plasma (AIP) were estimated using the Friedwald equation: (VLDL) = TG/5, (LDL) = TC - [TG/5 + HDL], (AIP) = Log (TG/HDL). TyG index was calculated using the formula: TyGi = ln [TG (mg/dL) × FBS (mg/dL)/2]. Serum zinc was measured using a commercially available kit supplied by Spectrum (REF 330 001, Germany) using the colorimetric test with 2-(5-Bromo-2-pyridylazo)-5-(N-propyl-N-sulfoproylamino)-phenol a red chelates complex, and absorbance was measured at 546nm. Serum copper was quantified using a commercially available kit supplied by Spectrum (REF 232 001, Germany) using the colorimetric test with 4-(3,5-Ddibromo-2-pyridylazo)-N-ethyl-sulfopropylaniline a chelate complex and absorbance was measured at 580nm, Magnesium was quantified in serum using a commercially available kit supplied by BioSystems (COD 11797, Spain) using the colorimetric method with XYLIDYL BLUE, these trace elements concentrations were measured using a JENWAY 6700 Visible Spectrophotometer.

Anthropometry And Blood Pressure Measurements:

Body weight in kg was recorded in the morning before eating, without shoes, utilizing a standard weighing scale. At the same time, height was measured with a standard measuring tape in an upright position. BMI = [weight (kg) / height² (m^2)] is applied to calculate body mass index (BMI). Following a 5-minute rest period, systolic blood pressure (SBP), diastolic blood pressure (DBP), and pulse rate were assessed using an electronic sphygmomanometer (ORIENTMED).

Statistical analysis:

SPSS Statistics software [IBM, version 26] is implemented to evaluate the statistical analysis. The Shapiro-Wilk test is used to determine the normal distribution of the data; data with normal and non-normal distributions are represented as mean ± SD. The two-group comparisons (SCHT vs. control) used the Student's t-test and the Mann-Whitney U test for normally and non-normally distributed variables, respectively. The three groups (tertiles of trace elements) were compared using the Kruskal-Wallis test for non-normally distributed variables or one-way analysis of variance (ANOVA) for normally distributed variables. The probable correlation between the analyzed values was investigated using Pearson correlation for normally distributed data and Spearman rank-order correlation for non-normally distributed data. We consider a p-value of less than 0.05 to be statistically significant.

3. RESULTS

Anthropometric and Biochemical Parameters in Control and SCHT Groups:

The comparison of different variables between individuals with SCHT and controls is shown in Table 1. The SCHT group had a mean age of 31.9 ± 7.72 years; whereas, the control group had a marginally higher mean age of 32.15 ± 8.65 years, with a non-significant difference between the SCHT and control groups ($p = 0.885$). The BMI was markedly elevated in SCHT ($p < 0.001$) in contrast to the healthy group. However, both SBP ($p = 0.679$) and DBP ($p = 0.887$) exhibit a non-significant difference between the SCHT and control groups. At the same time, PR was markedly reduced in the SCHT group ($p< 0.001$) in contrast to

the control group. TSH levels were considerably elevated in SCHT ($p < 0.001$) in contrast to the healthy group. Likewise, there were significant differences in levels of FT3 ($p = 0.005$) and FT4 ($p < 0.001$) between the two groups. FBS ($p = 0.026$), TC ($p = 0.001$), TG ($p < 0.001$), LDL-C ($p = 0.004$), VLDL-C ($p < 0.001$), TyGi ($p < 0.001$), AIP ($p < 0.001$), and hsCRP ($p = 0.006$) were considerably higher in the SCHT group in contrast to the healthy group, while HDL-C was significantly lower in the SCHT group in contrast to the healthy group ($p = 0.019$). Serum iron, Cu, UIBC, and TIBC show no significant difference between the groups. However, Zn ($p = 0.006$), Mg ($p < 0.003$), Ferritin ($p = 0.001$), and vitamin D ($p = 0.003$) were significantly lower in the SCHT group in contrast to the control group.

Table 1: Anthropometric and biochemical parameters in control and SCHT groups.

Variable	SCHT(n=50)	Control(n=40)	P-value
Age (years)	31.9 ± 7.72	32.15 ± 8.65	0.885
BMI (Kg/m^2)	29.71*** ± 9.55	24.06 ± 3.53	< 0.001
SBP (mmHg)	123.24 ± 9.32	122.58 ± 5.72	0.679
DBP (mmHg)	76.58 ± 11.49	77.83 ± 2.64	0.887
PR (pul/min)	86.32*** ± 8.27	94.98 ± 7.19	< 0.001
TSH (µIU/ml)	7.67*** ± 4.04	2.12 ± 0.77	< 0.001
FT3(pmol/L	5.11** ± 1.01	5.71 ± 0.92	0.005
FT4 (pmol/L)	15.05*** ± 2.42	17.82 ± 2.11	< 0.001
Zn (µg/dl)	94.27** ± 37.57	105.8 ± 32.57	0.006
Mg (mg/dl)	2.62** ± 0.38	2.93 ± 0.52	0.003
Cu (µg/dl)	105.82 ± 33.38	95.04 ± 22.06	0.070
FBS (mg/dL)	100.2* ± 14.57	94 ± 8.71	0.026
TC (mg/dL)	168.9** ± 35.16	145.7 ± 25.36	0.001
TG (mg/dL)	140.2*** ± 79.63	83.12 ± 36.58	< 0.001
HDL-C (mg/dL)	47* ± 15.32	51.22 ± 10.05	0.019
LDL-C (mg/dL)	93.34** ± 29.03	77.36 ± 21.51	0.004
VLDL-C (mg/dL)	28.04*** ± 15.93	16.63 ± 7.32	< 0.001
AIP	0.42*** ± 0.32	0.17 ± 0.23	< 0.001
TyGi	4.69*** ± 0.31	4.43 ± 0.21	< 0.001
Iron (µg/dl)	73.75 ± 35.02	83.22 ± 28.86	0.079
UIBC (µg/dl)	312.72 ± 74.72	290.69 ± 66.98	0.149
TIBC (µg/dl)	386.48 ± 53	373.80 ± 54.08	0.267
Ferritin (ng/ml)	20.63** ± 20.33	33.55 ± 21.42	0.001
hsCRP (mg/L)	3.2** ± 4.42	1.38 ± 1.63	0.006
Vitamin D (ng/ml)	21.31** ± 10.63	28.98 ± 14.68	0.003

Data are presented as mean ± SD for normally and non-normally distributed variables. p-value: <0.05 (*) is significant, <0.01 is high significant (**), $p < 0.001$ (***) statistical very high significant and >0.05 is not significant. SCHT: Subclinical hypothyroidism; BMI: Body mass index; DBP: Diastolic blood pressure; SBP: Systolic blood pressure; PR: Pulse rate; FT3: Free triiodothyronine; FT4: Free thyroxine; TSH: Thyroid stimulating hormone; FBS: Fasting blood sugar; TC: Total cholesterol; TG: Tri glyceride; HDL-C: High density lipoprotein cholesterol; VLDL-C: Very low-density lipoprotein cholesterol; LDL-C: Low density lipoprotein cholesterol; AIP: Atherogenic Index of Plasma; TyGi: Triglyceride-glucose index; Zn: Zinc; Mg: Magnesium; Cu: Copper; TIBC: Total iron binding capacity; UIBC: Unsaturated iron binding capacity; hsCRP: highly sensitive C-reactive protein.

Correlation of TSH Level with Several Anthropometric and Biochemical Variables in Studied Subjects:

Table 2 presents a correlation between TSH level and various variables of the studied subjects. Correlation analysis indicated a non-significant association of TSH with age, SBP, DSP, HDL-C, LDL-C, Iron, UIBC, TIBC, and Cu ($p = 0.800$, $p = 0.603$, $p = 0.988$, $p = 0.324$, $p = 0.097$, $p = 0.064$, $p = 0.289$, $p = 0.428$, $p = 0.097$), respectively. TSH exhibited a significant positive correlation with BMI, FBS, TC, TG, VLDL, AIP, TyGi, and hsCRP ($p = 0.002$, $p = 0.024$, $p = 0.005$, $p = 0.002$, $p = 0.002$, $p = 0.013$, $p = 0.001$, $p = 0.035$), respectively. In contrast, significant negative correlations were detected between TSH and PR ($p < 0.001$), FT3 ($p = 0.001$), FT4 ($p < 0.001$), Zn ($p = 0.001$), Mg ($p = 0.001$), Ferritin ($p < 0.001$), and vitamin D ($p = 0.004$).

Table 2: Correlation between TSH level and various anthropometric and biochemical variables in the studied subjects.

Variable	R	P-value
Age (years)	-0.027	0.800
BMI (Kg/m^2)	0.326**	0.002
SBP (mmHg)	0.056	0.603
DBP (mmHg)	0.002	0.988
PR (pul/min)	-0.429***	< 0.001
FT3(pmol/L	-0.331**	0.001
FT4 (pmol/L)	-0.560***	< 0.001
Zn (µg/dl)	-0.338**	0.001
Mg (mg/dl)	-0.354**	0.001
Cu (µg/dl)	0.188	0.076
FBS (mg/dl)	0.238*	0.024
TC (mg/dl)	0.295**	0.005
TG (mg/dl)	0.324**	0.002
HDL-C (mg/dl)	-0.107	0.324
LDL-C (mg/dl)	0.176	0.097
VLDL-C (mg/dl)	0.324**	0.002
AIP	0.261*	0.013
TyGi	0.334**	0.001
Iron (µg/dl)	-0.196	0.064
UIBC (µg/dl)	0.113	0.289
TIBC (µg/dl)	0.085	0.428
Ferritin (ng/ml)	-0.383***	< 0.001
hsCRP (mg/L)	0.223*	0.035
Vitamin D (ng/ml)	-0.298**	0.004

r = Spearman's rank correlation coefficient. *Correlation at 0.05 is statistically significant, **Correlation at 0.01 is highly significant, and ***Correlation at 0.001 is very highly significant.

Correlation of Vitamin D Levels and Ferritin Levels with Cardiometabolic Risk Factors:

Table 3 demonstrates the association between Vitamin D and Ferritin levels and cardiometabolic risk factors. Correlation analysis indicated a significant negative association between Vitamin D and TG, VLDL, and AIP ($p = 0.029$, $p = 0.029$, $p = 0.042$), respectively, in all studied objects. On the other hand, a considerable negative association was found between serum ferritin and TG ($p = 0.048$) and VLDL ($p = 0.048$).

Table 3: Correlation of Vitamin D levels and ferritin levels with cardiometabolic risk factors.

	Ferritin (ng/ml)		Vitamin D (ng/ml)	
Variable	R	P-value	R	P-value
BMI (Kg/m^2)	-0.147	0.166	-0.099	0.355
SBP (mmHg)	-0.194	0.067	0.192	0.070
DBP (mmHg)	0.007	0.945	0.096	0.370

PR (pul/min)	0.176	0.096	0.178	0.094
FBS (mg/dl)	-0.046	0.663	-0.42	0.696
TC (mg/dl)	-0.145	0.174	-0.149	0.162
TG (mg/dl)	-0.209*	0.048	-0.231*	0.029
HDL-C (mg/dl)	0.138	0.196	0.026	0.807
LDL-C (mg/dl)	-0.121	0.251	-0.108	0.311
VLDL-C (mg/dl)	-0.209*	0.048	-0.231*	0.029
AIP	-0.191	0.071	-0.215*	0.042
TyGi	-0.102	0.337	-0.140	0.189
hsCRP (mg/L)	-0.025	0.814	-0.027	0.797

r = Spearman's rank correlation coefficient.

Correlation of serum Zinc, Magnesium, Copper, and iron with cardiometabolic risk factors:

Table 4 shows the association between serum Zn, Mg, Cu, and Fe with cardiometabolic risk factors. Correlation analysis revealed a significant positive association between serum Zinc and PR (p = 0.008) and a significant negative association between zinc and BMI (p = 0.049) across all studied objects. Furthermore, a considerable negative association was found between serum Magnesium and BMI (p = 0.039), TyGi (p = 0.047), and hsCRP (p = 0.001). Moreover, a significant positive association was noted between serum copper and TyGi (p = 0.047) and hsCRP (p = 0.013). On the other side, a considerable negative association was found between serum Iron and BMI (p = 0.014) and hsCRP (p = 0.001).

Table 4: Correlation of serum Zinc, Magnesium, Copper, and iron with cardiometabolic risk factors.

	Zinc (ng/dl)		**Magnesium (mg/dl)**		**Copper (ng/dl)**		**Iron (ng/dl)**	
Variable	**R**	**P-value**	**R^2/r**	**P-value**	**R^2/r**	**P-value**	**r**	**p-value**
BMI(Kg/m^2)	-0.208*	0.049	-0.218*	0.039	0.162	0.128	-0.257*	0.014
DBP (mmHg)	-0.166	0.117	-0.088	0.409	0.081	0.450	-0.111	0.298
SBP (mmHg)	0.124	0.244	-0.001	0.990	-0.048	0.650	-0.044	0.682
PR (pul/min)	0.280**	0.008	0.061	0.567	-0.013	0.904	0.079	0.435
FBS (mg/dl)	-0.111	0.299	-0.067	0.531	0.180	0.090	-0.044	0.683
TC (mg/dl)	0.075	0.481	-0.100	0.346	0.132	0.214	-0.021	0.841
TG (mg/dl)	-0.059	0.580	-0.068	0.524	0.114	0.284	-0.055	0.606
HDL-C (mg/dl)	-0.009	0.932	0.011	0.921	-0.001	0.989	0.146	0.170
LDL-C (mg/dl)	0.073	0.493	-0.092	0.388	0.083	0.435	-0.024	0.824
VLDL-C (mg/dl)	-0.059	0.580	-0.068	0.524	0.114	0.284	-0.055	0.606
AIP	-0.045	0.673	-0.084	0.430	0.125	0.242	-0.097	0.363
TyGi	-0.117	0.274	-0.211*	0.047	0.210*	0.047	-0.106	0.318
hsCRP (mg/dl)	-0.066	0.534	-0.320**	0.001	0.261*	0.013	-0.341**	0.001

r = Spearman's rank correlation coefficient, R^2 = Pearson correlation coefficient.

Comparison of Cardiometabolic Risk Factors Based on Zn, Mg, Cu, and Fe Tertiles:

A comparison of Cardiometabolic risk factors based on Zn, Mg, Cu, and Fe tertiles is presented in Table 5. Results indicated a significant difference in PR (p = 0.020) levels between Zn tertiles. A decrease in PR levels was noted with a decrease in serum Zn. Furthermore, a considerable difference in TC (p = 0.032) levels are found between Mg tertiles. An increase in levels of TC was noted with a decrease in Mg levels. Moreover, a remarkable elevation is found in hsCRP (p = 0.005) with decreasing serum Fe.

Table 5: Comparison of Cardiometabolic risk factors based on Zn, Mg, Cu, and Fe tertiles.

	Zinc Tertiles				**Magnesium Tertiles**			
Variable	**T1 (n=29) < 83.16**	**T2 (n=31) 83.16-100.74**	**T3 (n=30) > 100.74**	**p-value**	**T1 (n=30) < 2.52**	**T2 (n=31) 2.52 – 2.86**	**T3 (n=29) > 2.86**	**p-value**
BMI(Kg/m^2)	29.2 (6.76)	26.97 (10.5)	25.49 (5.55)	0.200	28.69 (6.84)	27.36 (10.6)	25.48 (5.22)	0.303
DBP (mmHg)	78.34 (6.52)	78.03 (4.52)	75.03 (12.8)	0.272	78 (7.18)	77.52 (3.66)	75.83 (13.1)	0.610
SBP (mmHg)	122 (8.53)	123.9 (8.21)	122.9 (7.03)	0.661	123.6 (7.88)	122.5 (6.56)	122.8 (9.3)	0.862
PR (pul/min)	86.48* (9.88)	91.26* (7.74)	92.6* (8.34)	0.020	91.3 (9.79)	88.23 (9.04)	91.07 (7.53)	0.326
FBS (mg/dl)	101.4 (17.6)	96.8 (9.74)	94.6 (8.31)	0.129	100.8 (17.5)	94.8 (7.47)	96.84 (10.6)	0.174
TC (mg/dl)	162.3 (31.6)	153 (35.7)	160.9 (32.1)	0.505	170.8* (27.8)	149.1* (30.9)	156.2* (37.3)	0.032
TG (mg/dl)	120.3 (59)	107.6 (75.9)	116.9 (74.9)	0.769	122.7 (60.8)	106.4 (69.9)	115.8 (79.6)	0.664
HDL-C (mg/dl)	49.6 (17.13)	48.4 (10.5)	48.69 (12.2)	0.940	51.62 (16.9)	46.81 (10.2)	48.26 (11.9)	0.357
LDL-C (mg/dl)	87.03 (24.7)	82.95 (28.3)	88.9 (28.3)	0.686	93.77 (22.8)	80.64 (24.6)	84.43 (32.2)	0.151
VLDL-C (mg/dl)	24.07 (11.8)	21.52 (15.2)	23.39 (14.9)	0.769	24.53 (12.2)	21.28 (13.9)	23.16 (15.9)	0.664
AIP	0.35 (0.29)	0.27 (0.31)	0.32 (0.33)	0.619	0.34 (0.29)	0.29 (0.28)	0.31 (0.35)	0.899
TyGi	4.58 (0.28)	4.55 (0.32)	4.59 (0.29)	0.891	4.62 (0.29)	4.55 (0.29)	4.55 (0.33)	0.545
hsCRP (mg/dl)	3.55 (4.81)	1.84 (3.21)	1.84(2.01)	0.105	2.75 (3.84)	3 (4.4)	1.37 (1.81)	0.168

	Copper Tertiles				**Iron Tertiles**			
Variable	**T1 (n=30) < 84.74**	**T2 (n=31) 84.74–107.02**	**T3 (n=29) > 107.02**	**p-value**	**T1 (n=30) < 59.94**	**T2 (n=30) 59.94- 87.37**	**T3 (n=30) > 87.37**	**p-value**
BMI(Kg/m^2)	25.72 (4.69)	27.78 (10.9)	28.1 (6.95)	0.462	28.53 (5.76)	27.79 (11)	25.26 (5.87)	0.252
DBP (mmHg)	76.4 (4.88)	76.6 (13.7)	78.5 (3.73)	0.604	76.27 (8.87)	78.47 (3.84)	76.67 (4.49)	0.587
SBP (mmHg)	122.9 (8.35)	124.5 (7.46)	121.3 (7.77)	0.286	124.6 (8.65)	122.1 (7.48)	122.1 (7.37)	0.392
PR (pul/min)	88.9 (8.18)	92.32 (7.13)	89.1 (10.9)	0.250	88.03 (8.66)	90.5 (9.23)	91.97 (8.6)	0.225
FBS (mg/dl)	97.15 (9.01)	974.7 (8.1)	100.7 (18.3)	0.180	95.97 (8.1)	99.88 (18.3)	96.5 (8.91)	0.435
TC (mg/dl)	156.6 (32.3)	157.8 (36.7)	161.5 (31)	0.842	156.6 (36.1)	155.7 (35.4)	163.6 (27.8)	0.604
TG (mg/dl)	108.2 (55.9)	120 (78.7)	116.2 (74.1)	0.801	117.1 (55.8)	105.3 (76.6)	122.1 (76.5)	0.635
HDL-C (mg/dl)	49.4 (12.8)	47.82 (16.3)	49.5 (10.4)	0.864	46.03 (11.2)	50.26 (15.8)	50.34 (12.6)	0.362
LDL-C (mg/dl)	84.8 (27.5)	85.08 (25.5)	88.96 (28.8)	0.808	86.35 (31)	84.2 (25.3)	88.2 (24.35)	0.835

VLDL-C (mg/dl)	21.63 (11.4)	24 (15.4)	23.25 (14.8)	0.801	23.42 (11.6)	21.05 (15.3)	24.43 (15.3)	0.635
AIP	0.29 (0.3)	0.34 (0.32)	0.31 (0.31)	0.868	0.36 (0.27)	0.27 (0.32)	0.33 (0.32)	0.317
TyGi	4.51 (0.28)	4.57 (0.31)	4.64 (0.29)	0.230	4.58 (0.32)	4.57 (0.32)	4.55 (0.31)	0.878
hsCRP (mg/dl)	1.75 (2.19)	1.92 (1.71)	3.55 (5.5)	0.100	4.05** (5.19)	1.95** (2.56)	1.18** (1.03)	0.005

Results are represented as Mean (SD).

4. DISCUSSION

Cardiovascular disease (CVD) is associated with both subclinical and clinical hypothyroidism, which disrupts normal endothelium function through pathways including inflammation, lipid abnormalities, and oxidative stress (Sami *et al*., 2024). This study investigates the impact of vitamin D status, iron profiles, and trace elements imbalance on cardiometabolic risk factors. Our study indicated a significant increase in cardiometabolic risk factors such as fasting blood sugar, lipid profile, AIP, TyGi, and hsCRP in SCHT. Furthermore, a strong association was noted between elevating TSH and TC, TG, VLDL-c, fasting blood sugar, AIP, and TyGi. Additionally, a substantial correlation was noted between reduced vitamin D, ferritin, magnesium, iron, and elevated serum copper with cardiometabolic risk factors.

The SCHT group had a notable elevation in BMI relative to the healthy group, aligning with findings of (Mahat *et al*., 2023). A substantial positive association was determined between TSH and BMI. Research has indicated a positive correlation between BMI and TSH, suggesting that changes in body weight are correlated with thyroid disease (Kirac *et al*., 2022; Mahat *et al.,* 2023). Both SBP and DBP were found to be nonsignificant between SCHT and the control group, which aligns with those of Luo *et al,* (2022).

The SCHT group showed significantly elevated levels of TG, TC, VLDL-C, and LDL-C and a considerably lower level of HDL-C in contrast to the control group, which is in agreement with the findings of Lamichhane *et al.* (2023) and Liu *et al* (2023). The precise pathophysiology of dyslipidemia in hypothyroidism remains ambiguous; however, multiple explanations have been suggested. A variety of mechanisms are involved in the accumulation of LDL-c, the emergence of hypertriglyceridemia as a result of reduced lipoprotein lipase activity, and the reduced clearance of cholesterol from the bloodstream due to the liver's impaired capacity to convert cholesterol into bile acids (Cicatiello *et al.*, 2018; Nicolaou & Toumba, 2024). TSH exhibited a substantial positive association with TC, TG, and VLDL-c. Cardiovascular risk variables, including cholesterol levels, arterial blood pressure, and BMI, have been linked to elevated TSH levels in adults, even when they are within the normal range. Certain studies have even linked high-normal TSH levels to the onset of metabolic syndrome (Meisinger *et al.*, 2014; Ramouzi *et al.,* 2024).

AIP is regarded as a significant marker consisting of TG and HDL-C, extensively utilized for quantifying lipid levels and deemed the most effective indicator for assessing CVD and dyslipidemia (Zhu *et al.,* 2018). This study identified significantly higher AIP levels in the SCHT group in contrast to the healthy group. A substantial positive association was identified between TSH and AIP. These findings correspond with research conducted by Lamichhane *et al.* (2023). Elevated TG and decreased HDL-C compared to normal euthyroid controls cause elevated AIP in SCHT. Subclinical hypothyroid women had an increased risk of CDV compared to euthyroid women, according to their average AIP (Hossain *et al.*, 2021).

A newly proposed surrogate marker of insulin resistance (IR) is the TyGi, which is a product of fasting triglycerides and glucose (Choi *et al.,* 2021). Multiple studies have indicated that elevated TyGi correlates with the onset of cardiometabolic disorders (Kitae *et al.,* 2019; Barzegar *et al.*, 2020). The results showed that the SCHT group had substantially higher TyGi levels than the control group. In addition, TSH and TyGi were discovered to have a very positive correlation (Mahat *et al*., 2023).

Vitamin D levels were found to be markedly lower in the SCHT group compared to the control group in a recent study. Vitamin D and TSH were also found to have a strong inverse relationship. The results corroborate the findings of the study conducted by Sari and Coşkuner (2022); Mahat *et al*., 2023). Inadequate intestinal absorption and impaired vitamin D activation may explain why individuals with SCHT have lower vitamin D levels (Talaei *et al.*, 2018). Additionally, vitamin D supplementation improves blood TSH, according to a study conducted on subclinical hypothyroid patients (Safari *et al*., 2023).Vitamin D insufficiency is linked with cardiometabolic risk factors, including insulin resistance, obesity, dyslipidemia, and hypertension (Milagres *et al.,* 2017; Mousa *et al.*, 2017). The results of this study show that low vitamin D levels are inversely related to high TG and very LDL-c. Vitamin D and AIP were also found to have a negative correlation, suggesting that SCHT patients may be at a higher risk of developing CVD. Findings from our study are in line with previous research showing that low vitamin D levels are linked with an increased risk of CVD and death in individuals with dyslipidemia (Alsamghan *et al.*, 2020; Hu *et al*., 2024).

Ferritin levels were found to be considerably lower in the SCHT group compared to the control group in the present study. The association between ferritin and TSH was also significantly negative. These results are similar to those found by Sylus *et al*. (2024) and Gupta *et al.* (2024). Reduced ferritin levels, a measure of the body's iron stores, impact thyroid hormone synthesis. Decreased ferritin levels impact thyroid hormone production and the conversion of T4 to its active form, T3. A sufficient amount of iron is needed for this conversion, which primarily occurs in the liver (Krishnamurthy *et al*., 2023). In contrast to erythroid, researchers found that iron insufficiency was more common in SCHT patients (Swapnika *et al.,* 2024). Additionally, a remarkable negative association was noted between serum ferritin and TG and VLDL-c. Research conducted by Kadoglou *et al* (2017) found that low ferritin levels in women with no significant chronic disease are correlated with elevated all-cause mortality.

Moreover, the serum zinc levels of the SCHT group were substantially lower than those of the control group, and a significant negative association was noted between serum Zn and TSH. The study conducted by Patel *et al.,* (2024) agrees with these findings. Zn may impact the conversion of T4 to T3 because of its effect on hepatic deiodinase (DIO) activity; when Zn levels are low, the enzyme's activity decreases (Bryliński *et al.,* 2025). In addition, a considerable positive association between serum zinc and PR was noted, and a decrease in PR levels was noted with a decrease in serum Zn, indicating that low serum zinc could be a risk factor for developing CVD. Prior studies indicate that zinc deficiency can compromise cardiovascular function, whereas sufficient zinc levels correlate with elevated heart rate and heightened sympathetic tone in some contexts (Rosenblum *et al*., 2020; Hara *et al*., 2023).

In addition, serum magnesium was shown to decrease notably in the SCHT group in contrast to the control group, and a significant negative association was noted between serum magnesium and TSH. These results align with those obtained by Athokpham *et al* (2020). Magnesium is crucial for the thyroid's use of iodine and the conversion of dormant T4 into active T3 (Zhou *et al*., 2022). Moreover, the results revealed a considerable negative association between serum Mg and BMI, TyGi, and hsCRP. These results indicate that low magnesium levels are linked to cardiometabolic risk factors. Magnesium performs numerous physiological activities in the body. These encompass vital functions in sustaining cardiovascular performance, contributing to the regulation of cardiac excitation–contraction coupling, hemostasis, and endothelial function (Fritzen *et al*., 2023). Numerous studies have associated inadequate magnesium consumption with the occurrence of specific cardiometabolic disorders (Dominguez *et al.*, 2020; Jiao *et al*., 2022).

Additionally, serum copper was shown to slightly increase in SCHT in contrast to controls, but the results were statistically nonsignificant between the groups. Research indicates that diminished copper levels may correlate with hyperthyroidism, whilst elevated levels may be associated with hypothyroidism (Zhou *et al.*, 2022). Furthermore, a considerably positive association was noted between serum copper and TyGi and hsCRP these results indicated a link between elevated serum copper and cardiometabolic risk factors. Copper is an essential mineral, and an adequate quantity of copper is necessary to facilitate appropriate physiological functions across multiple systems, including the cardiovascular system (Chen *et al.*, 2023). A study on the women population of China found a significant positive association between serum copper and TC, TG, LDL, and inflammation markers (Chen *et al.*, 2021).

The current study has limitations that must be acknowledged when interpreting the results, specifically its cross-sectional design and the limited sample size (n = 90). Further longitudinal and interventional research is necessary to confirm this correlation and explore its clinical implications.

CONCLUSION

The current study concluded that low vitamin D, ferritin, magnesium levels, and elevated copper levels could be associated with cardiometabolic risk factors in females with newly diagnosed subclinical hypothyroidism. Reduced vitamin D, zinc, and magnesium levels, disrupted iron metabolism, and elevated serum copper were linked to heightened atherogenic risk and metabolic abnormalities. This study indicates that the surveillance and enhancement of vitamin D, zinc, magnesium, and iron levels may contribute to the management of cardiovascular risk in women with subclinical hypothyroidism. However, because of the cross-sectional nature of this study, further longitudinal and interventional research is required to determine causal relationships and clinical implications.

Acknowledgment:

We sincerely extend our gratitude to the staff of the Zakho General Hospital Lab and all the participants who voluntarily agreed to participate in this research work.

Ethical Statement:

The research has been conducted according to ethical principles of the Helsinki Declaration and the local Bioethics Committee at the Medicine College, University of Zakho (NOV2024/UOZE25). Participants were individually informed about the study's purpose. The subjects participated voluntarily, and written and verbal consent was obtained from all the subjects before biochemical measurements were performed.

Author Contribution:

C. H. S., sample collection, methodology, data analysis, and writing. L. Y. M. and M. A. H. conceptualized, and all authors critically reviewed the content of the manuscript. All authors have read and agreed to the published version of the manuscript.

REFERENCE

Abdulmawjood, S., & Altamer, Z. (2024). The relationship of hypothyroidism to iron deficiency in the body: Review Article. *NTU Journal of Pure Sciences*, *3*(1). https://doi.org/10.56286/ntujps.v3i1.516

Ahi, S., Dehdar, M. R., & Hatami, N. (2020). Vitamin D deficiency in non-autoimmune hypothyroidism: a case-control study. *BMC Endocrine Disorders*, *20*(1), 41. https://doi.org/10.1186/s12902-020-0522-9

Alsamghan, A. S., Alsaleem, S. A., Alzahrani, M. A. S., Patel, A., Mallick, A. K., & Sheweita, S. A. (2020). Effect of Hypovitaminosis D on Lipid Profile in Hypothyroid Patients in Saudi Arabia. *Oxidative Medicine and Cellular Longevity*, *2020*, 1–8. https://doi.org/10.1155/2020/6640402

Appunni, S., Rubens, M., Ramamoorthy, V., Saxena, A., Tonse, R., Veledar, E., & McGranaghan, P. (2021). Association between vitamin D deficiency and hypothyroidism: results from the National Health and Nutrition Examination Survey (NHANES) 2007–2012. *BMC Endocrine Disorders*, *21*(1), 224. https://doi.org/10.1186/s12902-021-00897-1

Athokpham, D., Mohanty, S., & Pinnelli, V. B. (2020). Status of Serum Calcium, Phosphorus, Magnesium and Copper in Hypothyroid Patients- A Case Control Study. *JOURNAL OF CLINICAL AND DIAGNOSTIC RESEARCH*. https://doi.org/10.7860/JCDR/2020/44711.14094

Barragán, R., Sánchez-González, C., Aranda, P., Sorlí, J. V., Asensio, E. M., Portolés, O., Ortega-Azorín, C., Villamil, L. V., Coltell, O., Llopis, J., Rivas-García, L., & Corella, D. (2022). Single and Combined Associations of Plasma and Urine Essential Trace Elements (Zn, Cu, Se, and Mn)

with Cardiovascular Risk Factors in a Mediterranean Population. *Antioxidants*, *11*(10), 1991. https://doi.org/10.3390/antiox11101991

Barzegar, N., Tohidi, M., Hasheminia, M., Azizi, F., & Hadaegh, F. (2020). The impact of triglyceride-glucose index on incident cardiovascular events during 16 years of follow-up: Tehran Lipid and Glucose Study. *Cardiovascular Diabetology*, *19*(1), 155. https://doi.org/10.1186/s12933-020-01121-5

Bílek, R., Dvořáková, M., Grimmichová, T., & Jiskra, J. (2020). Iodine, Thyroglobulin and Thyroid Gland. *Physiological Research*, S225–S236. https://doi.org/10.33549/physiolres.934514

Biondi, B., Cappola, A. R., & Cooper, D. S. (2019). Subclinical Hypothyroidism. *JAMA*, *322*(2), 153. https://doi.org/10.1001/jama.2019.9052

Bryliński, Ł., Kostelecka, K., Woliński, F., Komar, O., Miłosz, A., Michalczyk, J., Biłogras, J., Machrowska, A., Karpiński, R., Maciejewski, M., Maciejewski, R., Garruti, G., Flieger, J., & Baj, J. (2025). Effects of Trace Elements on Endocrine Function and Pathogenesis of Thyroid Diseases—A Literature Review. *Nutrients*, *17*(3), 398. https://doi.org/10.3390/nu17030398

Chen, J., Lan, C., An, H., Jin, Y., Li, Q., Ge, S., Yu, Y., Shen, G., Pan, B., Xu, Y., Ye, R., Li, Z., & Wang, B. (2021). Potential interference on the lipid metabolisms by serum copper in a women population: A repeated measurement study. *Science of The Total Environment*, *760*, 143375. https://doi.org/10.1016/j.scitotenv.2020.143375

Chen, X., Cai, Q., Liang, R., Zhang, D., Liu, X., Zhang, M., Xiong, Y., Xu, M., Liu, Q., Li, P., Yu, P., & Shi, A. (2023). Copper homeostasis and copper-induced cell death in the pathogenesis of cardiovascular disease and therapeutic strategies. *Cell Death & Disease*, *14*(2), 105. https://doi.org/10.1038/s41419-023-05639-w

Choi, W., Park, J. Y., Hong, A. R., Yoon, J. H., Kim, H. K., & Kang, H.-C. (2021). Association between triglyceride-glucose index and thyroid function in euthyroid adults: The Korea National Health and Nutritional Examination Survey 2015. *PLOS ONE*, *16*(7), e0254630. https://doi.org/10.1371/journal.pone.0254630

Cicatiello, A. G., Di Girolamo, D., & Dentice, M. (2018). Metabolic Effects of the Intracellular Regulation of Thyroid Hormone: Old Players, New Concepts. *Frontiers in Endocrinology*, *9*. https://doi.org/10.3389/fendo.2018.00474

Dominguez, L. J., Gea, A., Ruiz-Estigarribia, L., Sayón-Orea, C., Fresán, U., Barbagallo, M., Ruiz-Canela, M., & Martínez-González, M. A. (2020). Low Dietary Magnesium and Overweight/Obesity in a Mediterranean Population: A Detrimental Synergy for the Development of Hypertension. The SUN Project. *Nutrients*, *13*(1), 125. https://doi.org/10.3390/nu13010125

Fritzen, R., Davies, A., Veenhuizen, M., Campbell, M., Pitt, S. J., Ajjan, R. A., & Stewart, A. J. (2023). Magnesium Deficiency and Cardiometabolic Disease. *Nutrients*, *15*(10), 2355. https://doi.org/10.3390/nu15102355

Gallagher, J. C., & Rosen, C. J. (2023). Vitamin D: 100 years of discoveries, yet controversy continues. *The Lancet Diabetes & Endocrinology*, *11*(5), 362–374. https://doi.org/10.1016/S2213-8587(23)00060-8

Giustina, A., Bilezikian, J. P., Adler, R. A., Banfi, G., Bikle, D. D., Binkley, N. C., Bollerslev, J., Bouillon, R., Brandi, M. L., Casanueva, F. F., di Filippo, L., Donini, L. M., Ebeling, P. R., Fuleihan, G. E.-H., Fassio, A., Frara, S., Jones, G., Marcocci, C., Martineau, A. R., … Virtanen, J. K. (2024). Consensus Statement on Vitamin D Status Assessment and Supplementation: Whys, Whens, and Hows. *Endocrine Reviews*, *45*(5), 625–654. https://doi.org/10.1210/endrev/bnae009

Gupta, K., Sahoo, D. S. S., Verma, D. S., & Mishra, D. J. (2024). Evaluation of iron profile level in subclinical hypothyroid: A pilot study. *International Journal of Life Sciences Biotechnology and Pharma Research*, *13*(6), 217–221. https://doi.org/10.69605/ijlbpr_13.6.41

Hamad, H. H., & Raziq, A. H. (2020). The Underlying Pathology of Autoimmune Thyroid Disease is Il-22 Independent. *Science Journal of University of Zakho*, *8*(2), 48–51. https://doi.org/10.25271/sjuoz.2020.8.2.710

Hami, M., Ibrahim, A., & Ahmed, M. (2016). The Status of Serum Zinc, Magnesium and Calcium in Type 2 Diabetic Patients and Their Correlation with Renal Function. *Science Journal of University of Zakho*, *4*(2), 208–212. https://doi.org/10.25271/2016.4.2.84

Hanna, H. W. Z., Rizzo, C., Abdel Halim, R. M., El Haddad, H. E., Salam, R., & El-Sayed Abou-Youssef, H. (2021). Vitamin D status in Hashimoto's thyroiditis and its association with vitamin D receptor genetic variants. *The Journal of Steroid Biochemistry and Molecular Biology*, *212*, 105922. https://doi.org/10.1016/j.jsbmb.2021.105922

Hara, T., Yoshigai, E., Ohashi, T., & Fukada, T. (2023). Zinc in Cardiovascular Functions and Diseases: Epidemiology and Molecular Mechanisms for Therapeutic Development. *International Journal of Molecular Sciences*, *24*(8), 7152. https://doi.org/10.3390/ijms24087152

Hossain, M. A., Atiquzzaman, -, Sharifuzzaman, M., Amin, F., Kabir, L., Sultana, D., & Islam Bhuiyan, M. S. (2021). Study of Fasting Lipid Profile in Patients with Subclinical Hypothyroidism in a Tertiary Care Hospital in Bangladesh. *Faridpur Medical College Journal*, *16*(1), 17–20. https://doi.org/10.3329/fmcj.v16i1.55731

Hu, T., Zhang, Y., Chen, Z., & Su, J. (2024). Relationship between serum vitamin D levels and the atherogenic index of plasma: a study based on NHANES database 2011–2018. *Frontiers in Nutrition*, *11*. https://doi.org/10.3389/fnut.2024.1468284

Jiao, Y., Li, W., Wang, L., Jiang, H., Wang, S., Jia, X., Wang, Z., Wang, H., Zhang, B., & Ding, G. (2022). Relationship between Dietary Magnesium Intake and Metabolic Syndrome. *Nutrients*, *14*(10), 2013. https://doi.org/10.3390/nu14102013

Kadoglou, N. P. E., Biddulph, J. P., Rafnsson, S. B., Trivella, M., Nihoyannopoulos, P., & Demakakos, P. (2017). The association of ferritin with cardiovascular and all-cause mortality in community-dwellers: The English longitudinal study of ageing. *PLOS ONE*, *12*(6), e0178994. https://doi.org/10.1371/journal.pone.0178994

Kalan Sari, I., & Coşkuner, M. A. (2022). The relationship between subclinical hypothyroidism and vitamin D. *Journal of Health Sciences and Medicine*, *5*(5), 1276–

1280. https://doi.org/10.32322/jhsm.1124332

Kirac, C. O., Sirikci, V., & Findikli, H. A. (2022). Comparison of triglyceride-glucose index and HOMA-IR as indicators of insulin resistance in obese women with subclinical hypothyroidism. *European Journal of Clinical and Experimental Medicine*, *20*(4), 412–416. https://doi.org/10.15584/ejcem.2022.4.5

Kitae, A., Hashimoto, Y., Hamaguchi, M., Obora, A., Kojima, T., & Fukui, M. (2019). The Triglyceride and Glucose Index Is a Predictor of Incident Nonalcoholic Fatty Liver Disease: A Population-Based Cohort Study. *Canadian Journal of Gastroenterology and Hepatology*, *2019*, 1–7. https://doi.org/10.1155/2019/5121574

Krishnamurthy, H. K., Reddy, S., Jayaraman, V., Krishna, K., Song, Q., Rajasekaran, K. E., Wang, T., Bei, K., & Rajasekaran, J. J. (2023). Association of Serum Ferritin Levels and Thyroid Hormones. *Open Journal of Clinical Diagnostics*, *13*(03), 68–79. https://doi.org/10.4236/ojcd.2023.133007

Kumar, S. B., Arnipalli, S. R., Mehta, P., Carrau, S., & Ziouzenkova, O. (2022). Iron Deficiency Anemia: Efficacy and Limitations of Nutritional and Comprehensive Mitigation Strategies. *Nutrients*, *14*(14), 2976. https://doi.org/10.3390/nu14142976

Lamichhane, A., Bista, P., Pokhrel, S., Bolakhe, K., Joshi, G., Aryal, S., Chhusyabaga, M., Shakya, J., & Bhatt, M. P. (2023). Assessment of Cardiovascular Disease Risk in Females with Subclinical Hypothyroidism. *Journal of Lipids*, *2023*, 1–7. https://doi.org/10.1155/2023/4440275

Liu, J., Chen, Y., Ren, B., He, Y., Li, F., Wang, L., Wan, S., Liu, L., & Shen, H. (2023). Alteration of Lipid Profile Between Subclinical Hypothyroidism and Well-Matched Controls: A Meta-Analysis. *Hormone and Metabolic Research*, *55*(07), 479–486. https://doi.org/10.1055/a-2081-4599

Luo, Y., Wu, F., Huang, Z., Gong, Y., & Zheng, Y. (2022). Assessment of the relationship between subclinical hypothyroidism and blood lipid profile: reliable or not? *Lipids in Health and Disease*, *21*(1), 137. https://doi.org/10.1186/s12944-022-01749-0

Mahat, R. K., Panda, G., Nayak, B. P., & Panda, S. (2023). Association of vitamin D with triglyceride-glucose index and cardiometabolic risk factors in subclinical hypothyroidism. *Human Nutrition & Metabolism*, *34*, 200226. https://doi.org/10.1016/j.hnm.2023.200226

Meisinger, C., Ittermann, T., Tiller, D., Agger, C., Nauck, M., Schipf, S., Wallaschofski, H., Jørgensen, T., Linneberg, A., Thiery, J., Kluttig, A., Greiser, K. H., Werdan, K., Burkhardt, K., & Völzke, H. (2014). Sex-Specific Associations Between Thyrotropin and Serum Lipid Profiles. *Thyroid*, *24*(3), 424–432. https://doi.org/10.1089/thy.2013.0259

Milagres, L. C., Rocha, N. P., Filgueiras, M. de S., Albuquerque, F. M. de, Castro, A. P. P., Pessoa, M. C., Gouveia Peluzio, M. do C., & Novaes, J. F. de. (2017). Vitamin D insufficiency/deficiency is associated with insulin resistance in Brazilian children, regardless of body fat distribution. *Public Health Nutrition*, *20*(16), 2878–2886. https://doi.org/10.1017/S136898001700194X

Mousa, A., Naderpoor, N., de Courten, M. P. J., Scragg, R., & de Courten, B. (2017). 25-hydroxyvitamin D is associated with adiposity and cardiometabolic risk factors in a predominantly vitamin D-deficient and overweight/obese but otherwise healthy cohort. *The Journal of Steroid Biochemistry and Molecular Biology*, *173*, 258–264. https://doi.org/10.1016/j.jsbmb.2016.12.008

Nicolaou, M., & Toumba, M. (2024). Lipid Profile Pitfalls in Subclinical Hypothyroidism Pathophysiology and Treatment. *Lipidology*, *1*(2), 105–116. https://doi.org/10.3390/lipidology1020008

Pál, É., Ungvári, Z., Benyó, Z., & Várbíró, S. (2023). Role of Vitamin D Deficiency in the Pathogenesis of Cardiovascular and Cerebrovascular Diseases. *Nutrients*, *15*(2), 334. https://doi.org/10.3390/nu15020334

Patel, A. M., Khan, S., Inam, A. M. H., Alam, R., & Khan, M. M. (2024). Determination of Serum Zinc and Phosphorus Levels in Patients with Hypothyroidism. *Biological Trace Element Research*, *202*(7), 3018–3024. https://doi.org/10.1007/s12011-023-03905-8

Ramouzi, E., Sveroni, K., Manou, M., Papagiannopoulos, C., Genitsaridi, S.-M., Tragomalou, A., Vourdoumpa, A., Koutaki, D., Paltoglou, G., Kassari, P., & Charmandari, E. (2024). The Impact of Thyroid Hormones on Cardiometabolic Risk in Children and Adolescents with Obesity, Overweight and Normal Body Mass Index (BMI): A One-Year Intervention Study. *Nutrients*, *16*(16), 2650. https://doi.org/10.3390/nu16162650

Rosenblum, H., Wessler, J. D., Gupta, A., Maurer, M. S., & Bikdeli, B. (2020). Zinc Deficiency and Heart Failure: A Systematic Review of the Current Literature. *Journal of Cardiac Failure*, *26*(2), 180–189. https://doi.org/10.1016/j.cardfail.2020.01.005

Safari, S., Rafraf, M., Malekian, M., Molani-Gol, R., Asghari-Jafarabadi, M., & Mobasseri, M. (2023). Effects of vitamin D supplementation on metabolic parameters, serum irisin and obesity values in women with subclinical hypothyroidism: a double-blind randomized controlled trial. *Frontiers in Endocrinology*, *14*. https://doi.org/10.3389/fendo.2023.1306470

Sami, S. S., Nemeh, F. A., Fakhry, M. G., & Kamal, H. T. (2024). Deficiency of Vitamin D In Patient With Primary Hypothyroidism And As Related Risk Factor For Cardiovascular Diseases. *European Journal of Medical Genetics and Clinical Biology*, *1*(6), 192–199. https://doi.org/10.61796/jmgcb.v1i6.643

Savarese, G., von Haehling, S., Butler, J., Cleland, J. G. F., Ponikowski, P., & Anker, S. D. (2023). Iron deficiency and cardiovascular disease. *European Heart Journal*, *44*(1), 14–27. https://doi.org/10.1093/eurheartj/ehac569

Swapnika, T. G., Sabitha Rani, S. S., Dipankar, S., Itagi, A. B. H., & Vamshidhar, I. S. (2024). A Comparative Study of Iron Status in Subclinical Hypothyroid and Euthyroid Subjects in a Tertiary Care Hospital. *Cureus*. https://doi.org/10.7759/cureus.52007

Sylus, A. M., Priyatharshini, M., Muraliswaran, P., & Lavanya, M. (2024). Correlation of Iron Deficiency Status with Thyroid Profile among Subclinical and Overt Hypothyroidism Patients Attending a Tertiary Care Hospital in Puducherry, India: A Cross-sectional Study. *Acta Medica International*, *11*(3), 197–202. https://doi.org/10.4103/amit.amit_88_24

Talaei, A., Ghorbani, F., & Asemi, Z. (2018). The effects of Vitamin D supplementation on thyroid function in hypothyroid patients: A randomized, double-blind, placebo-controlled trial. *Indian Journal of Endocrinology and Metabolism*, *22*(5), 584. https://doi.org/10.4103/ijem.IJEM_603_17

Wang, L., Zhao, G., & Sandeep, B. (2024). A review regarding the article 'systematic review and meta-analysis of levothyroxine effect on blood pressure in patients with subclinical hypothyroidism.' *Current Problems in Cardiology*, *49*(2), 102351. https://doi.org/10.1016/j.cpcardiol.2023.102351

Wróblewski, M., Wróblewska, J., Nuszkiewicz, J., Pawłowska, M., Wesołowski, R., & Woźniak, A. (2023). The Role of Selected Trace Elements in Oxidoreductive Homeostasis in Patients with Thyroid Diseases. *International Journal of Molecular Sciences*, *24*(5), 4840. https://doi.org/10.3390/ijms24054840

Zarmina Khan, Roffa, Junaid Ayaz Khan, Muhammad Imran Sharif, Ayesha Amir Basra, Sanaullah, Aima Atif, Cathrine Nixon, Saman Khan, & Binayok Das. (2025). Association Between Subclinical Magnesium Deficiency and Major Cardiovascular Events: A Systematic Review and Meta-Analysis. *Indus Journal of Bioscience Research*, *3*(5), 53–57. https://doi.org/10.70749/ijbr.v3i5.1398

Zhou, Q., Xue, S., Zhang, L., & Chen, G. (2022). Trace elements and the thyroid. *Frontiers in Endocrinology*, *13*. https://doi.org/10.3389/fendo.2022.904889

Zhu, X., Yu, L., Zhou, H., Ma, Q., Zhou, X., Lei, T., Hu, J., Xu, W., Yi, N., & Lei, S. (2018). Atherogenic index of plasma is a novel and better biomarker associated with obesity: a population-based cross-sectional study in China. *Lipids in Health and Disease*, *17*(1), 37. https://doi.org/10.1186/s12944-018-0686-8